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A Low-Cost Velocity Monitoring Approach for Sewage Pipeline Blockage Detection via CFD Simulation

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Abstract. Detecting and handling blockages in sewage pipelines are crucial tasks for the maintenance of urban areas, as debris accumulation in those infrastructures leads to severe environmental contamination. Current approaches to this problem include conventional methods such as CCTV and Acoustic sensors, which require intensive human labor, and innovative approaches utilizing machine learning which are still under development. This study thus introduces a simple, cost-effective and low-manpower method to monitor real-time blockages within a sewage system—by merely measuring the velocity of water flow at different positions. To evaluate the practicability of this approach, we utilize a CFD software to model rigid blockages with different heights in a virtual pipe to investigate the change in flow velocity at different positions from the blockage. Our results demonstrate that the velocity of water streams generally increases above the blockage, and then decreases as water travel to a farther distance. Furthermore, the comprehensive analysis of blockage height, detecting position and velocity enables us to establish a mapping relationship, which is a method that hopefully applies to real pipelines. The method can then deduce rational flow meter spacing for the effective detection of blockage position under different environments. With low cost and plain principles, this system offers distinct advantages for rural areas with minute economical support and technology development.

Keywords: Sewage pipeline blockage, Flow velocity monitoring, CFD simulation, Real-time detection, Rural pipeline maintenance

1. Introduction

The precipitation of waste and silt in combined sewer systems has always been an essential and yet stubborn problem in numerous populated regions. Previous studies have already spotted the persistent phenomenon of the consolidation and deposition of sediments and admitted the difficulties of predicting sedimentation under different circumstances [1,2].

Environmental factors such as intrusive tree branches and sparse soil are also considered as chief culprits, requiring even more effort to handle [3]. The situation intensifies especially during wet seasons, when sewer systems with blockages are more likely to cause overflows and flooding, transferring a large number of pollutants into the surrounding environment, thus contaminating local water bodies and ecosystems [4]. Although prevention is always better inevitable as mentioned, especially in areas concentrated with old sewage pipes and with limited capital. Therefore, it is

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essential for researchers to develop detection methods to efficiently locate blockages and implement targeted maintenance measures. Addressing to this problem, we proposed a simple and cost-effective method of locating sedimentation in a sewage system by measuring only the velocity of the sewage current.

2. Literary review

Previous studies presented a variety of methods for the detection of sewage system blockages.

In 2024, a reflected wave technique was utilized by emitting a 10 Hz sinusoidal air pressure wave into the drainpipe and observing the reflected wave signals. Although this technology non-intrusive and continuous monitoring, it is currently still based on a simplified test bench without further practices. Its accuracy is likely to decrease in complex environments [5].

Similarly, methods involving acoustic sensors have also widely explored throughout recent years. A wide range of detectors such as accelerometers, hydrophones, fiber optic sensors and ultrasonic sensors can be employed to locate blockages with algorithmic support. However, these technologies usually involve manual operation, which limited them to only the respondence of reported incidents, making them unable to achieve automated maintenance [6].

On the other hand, there are technologies already applied to provide continuous inspection. CCTV (Closed-Circuit Television) is a widely utilized method which directly transports real-time images to help identify blockages with high precision. Nevertheless, human labor is required to analyze the data if this technology is used alone [7]. Currently, the development of machine learning with advanced algorithm may approach this problem in a novel way. Models such as modified RegNet, dilation segmentation with conditional random field (DilaSeg-CRF), you only look once (YOLO) models and faster region-based convolutional neural network (Faster R-CNN) are available algorithms for classification, segmentation, and object detection, yet they are still under development with the demand of high cost [8]. Therefore, this entire system is temporarily immature for automatic detection, especially in developing regions with low economic status.

Magnetic flux leakage (MFL) detection, another widely utilized technology, also faces similar limitations. Traditional detection using this method are prone to disturbances and manual analysis of data, making misinterpretations and false alarms [9]. Optimization plans, such as the model enhanced by the article, are obviously still at experimental stages and lack broad application.

In summary, current technologies for blockage detection either require high-standard human labor and a high price or lack real-world applications. Therefore, the method proposed by the research showcases broad application prospects in underdeveloped areas.

3. The theory of pipeline flow

If a section of fluid is uncompressed and uninterrupted, the mass of water entering or exiting any cross section at a fixed time interval must be the same to ensure consistency. This then indicates a constant mass flow rate under our assumptions. To simplify, we assume two cross sections with areas of and and flow lines of uniform velocity V_1 and V_2. Since the mass flow rate is conserved and the fluid is uniform, the flow volume— the volume of fluid $V = V_1 = V_2$ transported in a certain time interval (t)—is also conserved. The volume is equal to the length (l) of the fluid multiplied by the area of the cross section (S) it travels through, which is $V = Sl$. Since the velocity is uniform, the length is the displacement in the direction of velocity (v), which is $l = vt$. We then have

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$$S_1 v_1 = S_2 v_2 \tag{1}$$

This is based on the continuity principle: assuming a uniform flow velocity, the velocity of water particles will generally increase as the cross-sectional area of a sewage pipe is reduced by blockages. In real situation, this pattern is still observable in a not rigorous way, though the velocity is no longer uniform. The flowing rate of the fluid in the pipeline is relative to the cross-section area available to the fluid. Therefore, by gathering the flow velocity inside the pipe, the change in flow rate through the pipeline can be observed, which theoretically enables us to predict the possible height, length and position of an occurring debris accumulation.

4. Experiment

This study aim to evaluate the feasibility of detecting blockages using only flow meters. To do so, we apply a simulator to observe the flow of water in pipelines, applying a geometrical indentation to simulate the blockage in reality. By measuring water flow rates at different positions for varying blockage heights, this study aims to construct a flow rate mapping in a virtual environment that correlates blockage height, flow meter position, and the detected flow velocity. This three-dimensional model thus hopefully reflects on the practicability of this detection method, and serves as the basic model reference in real applications.

4.1. Hypothesis

To enhance the feasibility and intuitiveness of the simulation, a spherical pipe was constructed and filled with pure, homogeneous, incompressible water, with all air gaps eliminated to exclude extraneous disturbance factors. Inside the pipeline, we used a depression to imitate the blockage, thus its shape is not affected by the flow of water, corresponding to a rigid blockage that can't be removed or piled up by the fluid. To imitate a section of pipe with consistent water flow, we applied the pattern of Poiseuille Flow at the entrance so that an initial speed distribution emerges as if the pipe is infinitely long.



Figure 1. Enter caption

4.2. Simulation model

A CFD software is used to simulate the condition of debris accumulation in a sewage pipe. A 10 centimeters radius hollow cylinder is modeled, and a small portion of it at the bottom is removed to simulate a blockage. The length of the whole simulated pipe is 2 meters, and there is a step between 0.1 and 0.3 meters from the left at the bottom of the pipe. Fig.1 shows the three-dimensional model of the pipe created in the stimulator. l represents the length, and d represents the diameter of the whole pipe, which remain constant throughout the simulation. Notably, h1 represents the vertical height using the central line of the blockage as the base of the blockages, and h_2 as seen in Fig.2 represents the height of the flow meters. The velocity of water particles in the middle of the pipe is

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usually bigger than those on the sides due to friction (Assumption 6). Our initial condition is controlled so that the central flow rate is 0.5m/s, flowing from left to right. We modify the height of the step as the key independent variable, using values of h_1 = 0, 2.5, 5.0, 7.5, 10, 12.5, 15cm, and set six scenarios correspondingly. The experimental conditions are shown by Table 1 below.

Table 1. Experimental conditions

Scenario	h1(cm)	d (cm)	l (m)
1	2.5	20	2
2	5.0	20	2
3	7.5	20	2
4	10.0	20	2
5	12.5	20	2
6	15.0	20	2

A series of flow rate at different positions of the same height is gathered corresponding to each of these blockages. Two rounds of measurements are taken at the level of and $h_2 = 15\,\text{cm}$ above the base of the pipe for each scenario. The flow meters are at the centers of their vertical cross-section at that height. Fig.2 shows a set of flow meters placed at the height of 10 cm.

Then, for each height of blockage, the pipe model produces the following result.



Figure 2. Flow meter placement at $h_2 = 10\,\text{cm}$ (central axis)

5. Results

5.1. Layer development correction

As seen in Fig.3, we observe a decreasing central flow rate on the condition of no blockage as it flows through the pipe. It is observed that the decline follows an exponential pattern at the central axis ($h_2 = 10\,\text{cm}$), as shown by the line of best fit in Fig.4. The change in y (δy) for each interval of x from x = 0 (δx = 0.02m) corresponds to the systematic error for each position. We then added δy to each central velocity collected in order to reconcile the decrement. However, Fig.3 also visualizes a subtle increasing pattern at the level of 5 cm deviation ($h_2 = 15\,\text{cm}$), further quantified by the best fit line in Fig.5. Using the same method, the measured velocities are modified, thus both sets of measurements are corrected.

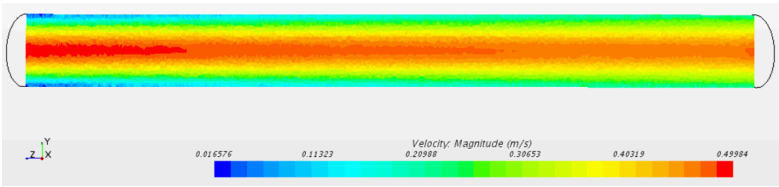

Figure 3. Velocity map for no blockage

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These subtle fluctuations are due to the shrinking range of the flow velocities, that the difference between central and edge velocity tends to minimize as the flow layers continue to develop along the pipe. The velocity of water is to be analyzed considering solely the influence of blockages, with the effects induced by boundary layer development thus eliminated.

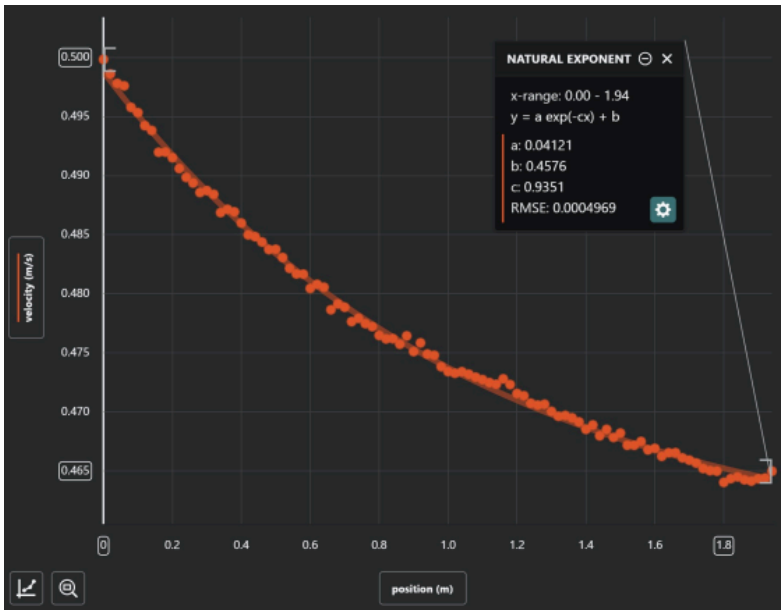

Figure 4. Speed decline at $h_2 = 10\,\text{cm}$

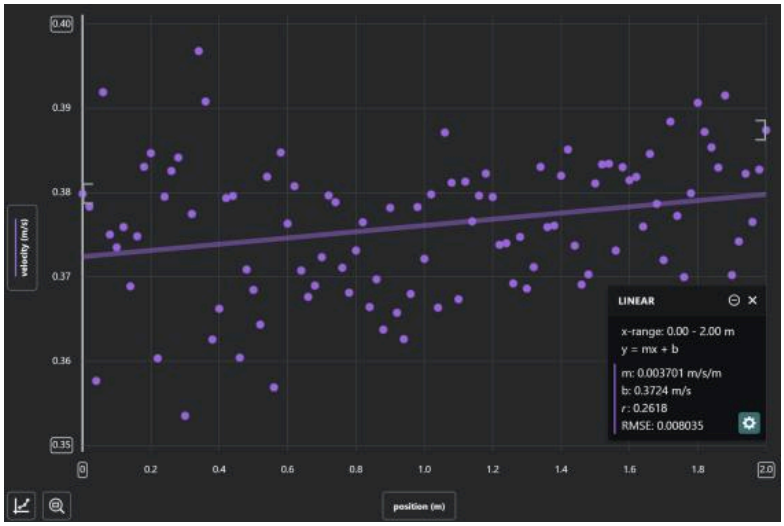

Figure 5. Speed increment at $h_2 = 15\,\text{cm}$

5.2. Fluid field conditions

Fig.6 shows the velocity distribution under different blockage heights. From all conditions, we can observe a significant acceleration right above the blockage, and a decreasing pattern after the blockage until the velocity approaches the initial settings. The blockages are not observed to have an influence on the fluid ahead of it. Using the collections at $h_2 = 10\,\text{cm}$ and $h_2 = 15\,\text{cm}$, a 3-dimensional relationship of block- age height(h) (cm), position(p) along the pipe (m) and flow velocity(v) (m/s) can be evaluated.

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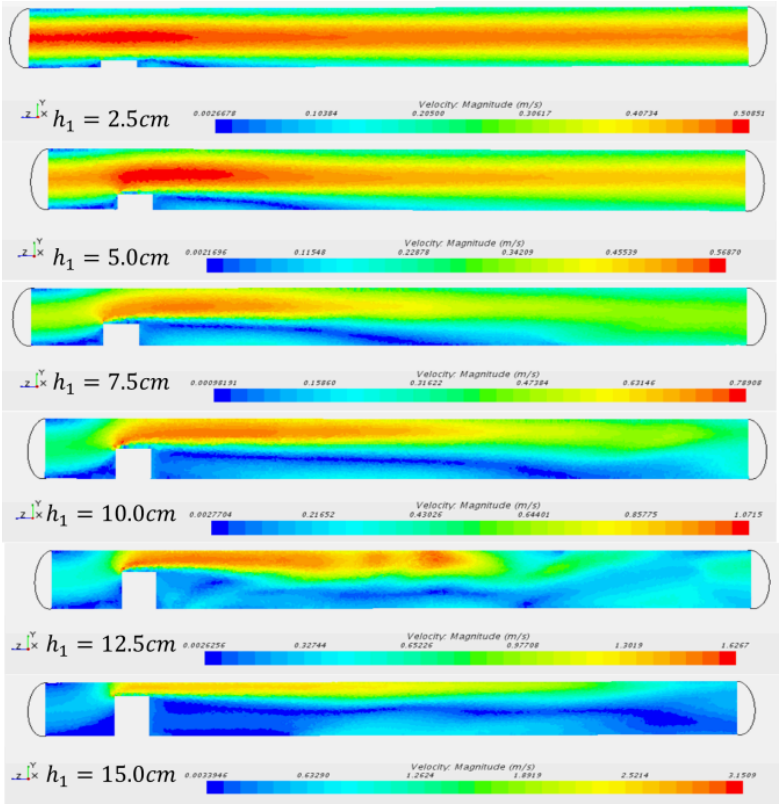

Figure 6. Vertical cross section at the sec- tor, color map of flow velocity with different blockage heights

5.3. Three-dimensional model of results

Two surfaces are plotted for the two data sets. Each of them visualizes the relationship between the position of the detector, the height of the blockage and the detected velocity. The blockage still appears between 0.1-0.3 m on the graph.

Fig.7 is the surface for $h_2 = 10\,\text{cm}$. The color of the map changes with the height of blockage, as shown by the color bar.

Observing from the position-velocity direction (Fig.8), we especially seek for universal patterns. For the heights below 10 cm, the velocity generally increases from 0.1 m and plateaus at 0.2-0.3 m, followed by a gradual decrement and returns to $0.5\,\text{m}\,\text{s}^{-1}$ at about 1 m. The average velocity above the blockage increases with blockage height, which satisfies the continuity principle. However, the velocity at 0.1-0.3 m for block- ages higher than 10 cm decreases to nearly 0 since the flow meters placed are below the blockages and thus no water can flow through it. Additionally, the measurements after the blockage are also relatively disordered. While we can see an increasing and then decreasing pattern for $h_1 = 12.5$, the velocity for and 15 falls below initial conditions and keeps fluctuating till the end. This is possibly due to the turbulence formed at a lower height as water passes the blockage and reenters the wider tube. Therefore, although cross section graphs demonstrate the pattern predicted, the velocity detected does not follow this trend if the blockage is higher than 10 cm, the level of detection. In these cases, this method shows less reliability and practicability.

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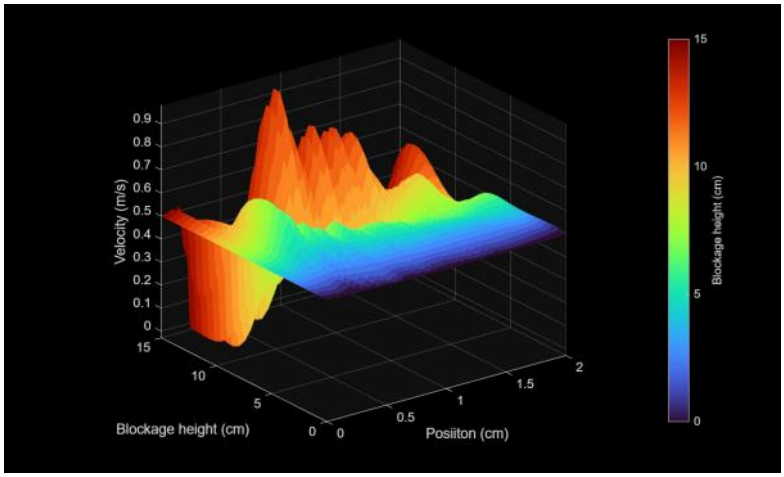

Figure 7. Velocity map of $h_2 = 10$ cm, three-dimensional viewpoint

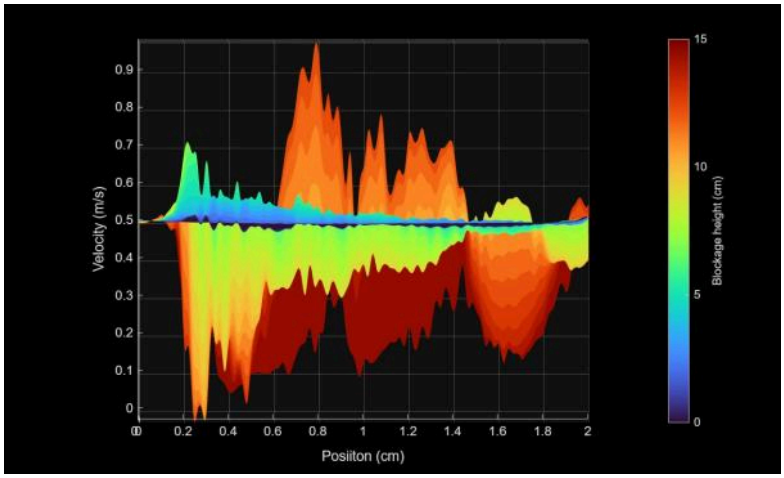

Figure 8. $h_2 = 10$ cm, position-velocity viewpoint

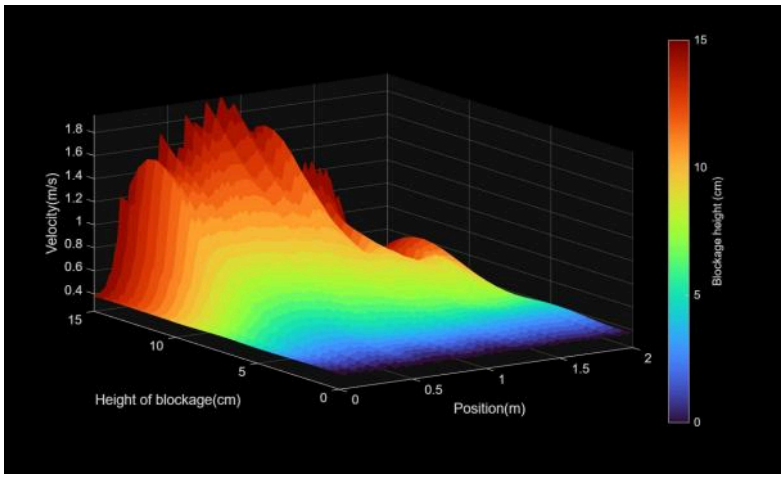

Figure 9. Velocity map at $h_2 = 15$ cm, three-dimensional viewpoint

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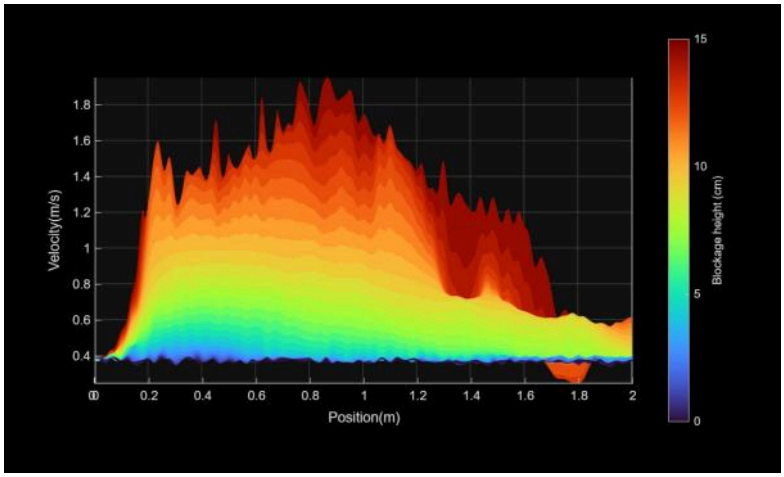

Figure 10. $h_2 = 15\,\text{cm}$, position-velocity viewpoint

Fig.9 shows the surface for flow meters at $h_2 = 15\,\text{cm}$, and Fig.10 again focuses on the relationship between position and velocity at this detection height. In this condition, the detection height is bigger or equal to all the blockages implemented.

Fig.10 shows that the velocity-position curve all satisfies a general increasing and then decreasing trend, featuring a big gradient at $x \in [0.1,0.2]$. For lower blockage, the velocity returns to initial conditions faster, and thus approaches to stability at around 0.5-1.8 m. But for blockages higher than 10 cm, the velocity may not return to initial conditions within the designed length of the pipe while it still starts to decrease from around 0.8 m.

Moreover, Fig. 11 shows is an additional viewpoint showing the relationship between the height of the blockage and the velocity. The shape of the graph effectively shows the maximum velocity detected under each condition. Given the absence of flow meter blockages, a positive correlation between blockage height and maximum flow velocity is evident from the upward slope in Fig. 11, which is also a pattern applicable when estimating the height of the blockage. This pattern is not obvious for the map at $h_2 = 10$ due to the chaotic results of high blockages.

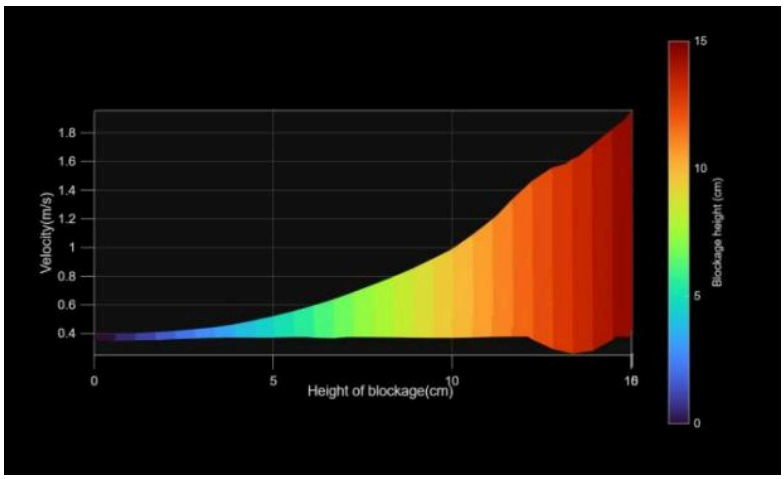

Figure 11. $h_2 = 15\,\text{cm}$, blockage height-velocity viewpoint

Summarizing the two surfaces, if the measurement is taken at a level above the blockage height, that the velocity always increases when entering the blockage, may or may not continue to increase

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depending on the height of the blockage, and starts to retreat after a distance. Higher blockages result in higher maximum velocity and longer retreat distance. Conversely, if the measurement is taken under the level of the blockage, the results are relatively unpredictable due to turbulence, which makes the method less applicable for detecting blockages. However, these data all feature a segment of numbers close to zero due to the invalidity of the flow meters in the blockage, which can still indicate the presence of severe abnormalities. Therefore, if the blockage is likely to accumulate at the bottom of a pipe (like the stimulated scenario), setting flow meters at a higher level promotes more accurate detection.

By following the contour lines of each surface, we can pack-push the combinations of different positions and heights (position, height) that satisfy a monitor result, but limited to further predictions. Thus, a single abnormal velocity only allows us to foresee a range of position and height, not enabling precise positioning and estimation of severity. Nevertheless, since the fluctuation is obvious around the blockage and retreats within a distance after the blockage, certain placement of flow meters with specific intervals still narrows the possibilities to down to between two flow meters. In our case, having a 0.02 m interval obviously creates a map that enables us to accurately detect the position and height of the blockage.

In reality, constructions are not enabling the placement of flow meters in every two centimeters along the pipe. However, similar settings are applicable in high-incidence regions. In these regions, placing flow meters with high density just as the simulation establishes accurate detection. On the other hand, in our simulation, a 50 cm interval between two flow meters still detects any notable blockages and locates them within two consecutive flow meters, as the condition with the lowest blockage tends to show a retreat to original velocities after 0.5 m on the position axis (Fig.10). Considering the worst situation, even if the blockage appears immediately after a flow meter, a 50 cm gap still enables the next flow meter to detect a higher velocity if the blockage is low, or a lower velocity if the blockage is high according to our model. This interval, as an estimation, will change when applied to reality due to more disturbances, yet it corresponds to a feasible solution for the large-scale application of this method.

6. Conclusion

The research utilizes a stimulation software to investigate the velocity distribution of water particles in a sewage pipe with different heights of blockages. A three-dimensional map is extracted from the detection results and an attempt to summarize the universal patterns of velocity is made. The results generally follow the theoretical trend despite some anomalies due to very high blockages.

At current stage, the simulation made it theoretically valid to infer a series of blockage position and height from one detected velocity, or locate the blockage precisely using several flow meters. This established mapping provided the numerical foundation for actual detections in reality to further examine the practicability of this method under different circumstances. For suitable environments of installing flow meters which don't require high-precision blockage detection, this method already has bright prospects of application.

However, the scale and reliability of the experimentation at present are still limited. Only a single set of simulations is done using a relatively simple and specific model compared to real situations. The current method also possesses low precision if the data is insufficient, since A long, low blockage may lead to the same readings as a short but high blockage if they are both lower than the detection level and happen to locate in the middle of two flow meters at different positions. Moreover, our model has made a lot of hypotheses that are invalid in actual sewage pipes. These limitations guaranteed a large room for improvement.

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In our further research, the simulation should be extended via repetitive experiments using different pipe sizes and blockage shapes with the additional parameter of blockage width. By comprehending the model within its assumptions, we hope to find a more universal pattern that is independent of blockage size and shape and improve the precision of our method when using fewer flow meters. Additionally, it is more significant to investigate the conditions that are closer to reality and excluded from our hypotheses. For example, simulations with heterogeneous water and flexible blockages can be examined to further enhance the practicability of this method.

References

[1] Jin, Y., Mukherjee, A., & Asce, A. (2010). Modeling Blockage Failures in Sewer Systems to Support Maintenance Decision Making. Journal of Performance of Constructed Facilities , 24(6). https: //doi.org/10.1061/

[2] Katayoun Kargar, & Darko Joksimovic. (2024). Blockage dynamics in sewer pipes: investigating snagging, accumulation, and dissipation rates of wet wipes. Water Science & Technology, 90(5), 1668–1680. https: //doi.org/10.2166/wst.2024.291

[3] Katayoun Kargar, & Darko Joksimovic. (2024a). Analysis of sewer block- age causes using open data. Water Practice & Technology, 19(9), 3855–3866. https: //doi.org/10.2166/wpt.2024.218

[4] Nguyen, M. T., Phuong, N. N., Saad, M., Tassin, B., Gillet, T., Gu´erin-Rechdaoui, S., Azimi, S., Rocher, V., Gasperi, J., & Dris, R. (2024). Microplastic accumulation in sewer sediments and its potential entering the environment via combined sewer overflows: a study case in Paris. Environmental Science and Pollution Research, 31(7), 10501–10507. https: //doi.org/10.1007/s11356-023-31734-8

[5] Kelly, D. A., Garden, M., Sharif, K., Campbell, D., & Gormley, M. (2024). A Novel Approach to Detecting Blockages in Sewers and Drains: The Reflected Wave Tech- nique. Buildings, 14(10), 3138–3138. https: //doi.org/10.3390/buildings14103138

[6] Yu, Y., Safari, A., Niu, X., Drinkwater, B., & Horoshenkov, K. V. (2021). Acoustic and ultrasonic techniques for defect detection and condition monitoring in water and sewerage pipes: A review. Applied Acoustics, 183, 108282. https: //doi.org/10.1016/j.apacoust.2021.108282

[7] Tang, J., Xia, J., Xie, Z., Li, Z., & Zhang, Y. (2025). A Method for Automatically Locating Defects in CCTV Inspection Data of Sewer Pipes. IEEE Access, 13, 135931–135949. https: //doi.org/10.1109/access.2025.3591031

[8] Nashat, M., & Zayed, T. (2025). A hybrid review of sewer inspection tools and automated CCTV image analysis techniques. Underground Space, 25, 295–326. https: //doi.org/10.1016/j.undsp.2025.06.004

[9] Zhang, L., Bian, Y., Jiang, P., Huang, Y., & Liu, Y. (2024). Improving Pipeline Magnetic Flux Leakage (MFL) Detection Performance With Mixed Attention Mechanisms (AMs) and Deep Residual Shrinkage Networks (DRSNs). IEEE Sensors Journal, 24(4), 5162–5171. https: //doi.org/10.1109/jsen.2023.3347510